

MONOLITHIC LOSS-OF-SIGNAL DETECT CIRCUITRY

5 CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of provisional Application 60/239,786, filed October 11, 2000, the disclosure of which is incorporated herein by reference.

10 BACKGROUND OF THE INVENTION

This invention relates generally to opto-electronic receivers and more specifically to loss-of-signal detection by an opto-electronic receiver.

High speed communication systems often transmit data using lightwaves transmitted over fiber-optic cables. Opto-electronic receivers receive the transmitted data as lightwaves, and form corresponding electrical signals for use by computerized systems.

In the receiver, the lightwaves generally impinge on a photodetector generating a current. The current is generally provided to a transimpedance amplifier where it is translated to a voltage and amplified. As the current is often small, care must often be used in designing the transimpedance amplifier, and possible further amplifying stages, to obtain useable signals.

It is sometimes useful for an opto-electronic receiver to have the ability to detect a Loss-of-Signal (LOS) occurrence. A LOS may occur for a variety of reasons and causes. A laser source may fail, a fiber optic cable may be sliced, or various other problems may occur. In addition, even a partial loss of signal strength may be sufficient to result in degraded system operation when an optical source, such as an optical source coupled to the opto-electronic receiver via a fiber optic cable, is disconnected.

The small current generated by the photodetector presents difficulties in monitoring for LOS. The use of, for example, a peak detector, may require greater signal strength, and therefore

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the use of a signal some distance down the amplification stage. Use of such a signal, however, may result in erroneous LOS
5 determination due to process, temperature, and other variations. Moreover, to avoid signal attenuation the components must often be placed close to the amplification stages, presenting layout difficulties.

10 SUMMARY OF THE INVENTION

The present invention provides a DC coupled Loss of Signal circuit. One embodiment of the invention comprises a loss of signal circuit. The loss of signal circuit is in an opto-electronic receiver, the opto-electronic receiver having a transimpedance amplifier AC coupled to a photodetector. The loss of signal circuit comprises a current-to-voltage circuit DC coupled to the photodetector, the current-to-voltage circuit receiving a DC current signal generated by the photodetector and providing a DC voltage signal. The loss of signal circuit further comprises a comparater coupled to the current-to-voltage circuit, the comparater receiving the DC voltage signal and providing a loss of signal signal.

In a further embodiment the invention comprises an opto-electronic receiver comprising a photodetector, a signal amplifier AC coupled to the photodetector, and a loss of signal circuit DC coupled to the photodetector. In one embodiment the signal amplifier comprises a transimpedance amplifier. In one embodiment the loss of signal circuit comprises a current to voltage circuit receiving a DC current signal and generating a DC voltage signal and a comparator comparing the DC voltage signal to a reference signal.

In a further embodiment the invention comprises an apparatus for generating a loss of signal signal for a photodetector circuit. The photodetector circuit is included in an opto-electronic receiver, with the photodetector circuit being AC

coupled to an amplifier stage and the photodetector circuit generating a DC signal responsive to an optical signal. The
5 apparatus comprises a current-to-voltage converter circuit receiving the DC signal from the photodetector circuit and generating a voltage signal in response to the DC signal, and a comparator circuit receiving a voltage signal from a current voltage converter circuit and generating an LOS signal. In a further embodiment the current-to-voltage converter further includes a current mirror circuit, a load resistor, and a voltage buffer circuit. In a further embodiment, the current to voltage converter circuit further includes a process and temperature compensator circuit.

15 In a further embodiment the invention comprises a method for generating a loss of signal signal for a photodetector circuit included in an opto-electronic receiver. In one embodiment the method comprises providing a current-to-voltage converter circuit preferably coupled to a photodetector circuit, providing a
20 comparator circuit operably coupled to the current voltage converter circuit and receiving by the current-to-voltage converter circuit from the photodetector circuit a DC signal. The method further comprises generating by the current-to-voltage converter circuit a voltage signal in response to the DC signal,
25 receiving by the comparator circuit the voltage signal, and generating by the comparator circuit an LOS signal.

In a further embodiment the invention comprises an apparatus for generating a loss of signal signal. The apparatus includes a current-to-voltage converter means coupled to the photodetector circuit for generating a voltage signal in response to a DC signal and comparator means coupled to the current-to-voltage converter means coupled to the current voltage converter means for generating a LOS signal in response to the voltage signal.

BRIEF DESCRIPTION OF THE DRAWINGS

5 These and other features, aspects, and advantages of the present invention will become better understood with regard to the following description and accompanying drawings where:

FIG. 1 is a block diagram of an opto-electronic receiver front-end including a Loss-Of-Signal (LOS) circuit in accordance with the present invention;

10 FIG. 2 is a block diagram of an opto-electronic receiver front-end including a LOS circuit in accordance with the present invention;

15 FIG. 3 is a graph showing the hysteresis of a comparator circuit in accordance with the present invention;

FIG. 4 is a block diagram of a current to voltage convertor circuit in accordance with the present invention; and

FIG. 5 is a circuit schematic of a current to voltage convertor circuit in accordance with the present invention.

20 DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a block diagram of an embodiment of an opto-electronic receiver front-end 10 including a Loss-Of-Signal (LOS) circuit 14 in accordance with the present invention. The opto-electronic receiver front-end includes a photodetector circuit

25 12. The photodetector circuit receives an optical signal (not shown). In response to the optical signal the photodetector generates a photodetector signal. The photodetector signal includes an AC component 18 and a DC component 17.

30 The AC component of the photodetector signal is provided to a transimpedance amplifier stage 19. The transimpedance amplifier stage amplifies the AC component of the photodetector signal and generates an AC voltage signal 20. The AC voltage signal is provided to a limiting amplifier stage 21. The limiting amplifier stage conditions the AC voltage signal to 35 create an output signal 22.

5 The DC component of the photodetector signal is provided to the LOS circuit 14. The LOS circuit generates an adjusted LOS signal 30 using the DC component of the photodetector signal. The adjusted LOS signal includes a state indicating the presence of an optical signal and a state indicating a loss of the optical signal.

10 The LOS circuit includes a current-to-voltage converter circuit 24. The current to voltage converter circuit receives the DC component of the photodetector signal generated by the photodetector circuit. The current-to-voltage converter circuit uses the DC component of the photodetector signal to generate a DC voltage signal 25. The DC voltage signal is provided to a 15 comparator circuit 26. The comparator circuit 26 compares the DC voltage signal to a reference voltage signal and generates a LOS signal 27. The LOS signal is provided to a translator circuit 28. The translator circuit receives the LOS signal and generates an adjusted LOS signal 30. The output levels of the 20 adjusted LOS signal are compatible with standard digital logic levels.

25 FIG. 2 is a block diagram of an embodiment of an opto-electronic receiver front-end including a Loss-Of-Signal (LOS) circuit. A photodetector circuit 12 includes a photodetector 100. The photodetector receives optical signals (not shown). A first end of the photodetector is coupled to a first biasing circuit 102, and a second end of the photodetector is coupled to a second bias circuit 104. The first biasing circuit is between a voltage source and the photodetector. The second biasing 30 circuit is between a LOS circuit and the photodetector. The LOS circuit is therefore DC coupled to the photo detector.

35 The first end of the photodetector is also coupled to a first capacitor 108. The second end of the photodetector is also coupled to a second capacitor 106. The capacitors provide signals to a transimpedance amplifier 110, with the capacitors

blocking DC components of the signals. The transimpedance amplifier is therefore AC coupled to the photodetector, with the
5 signals forming a differential signal.

Feedback for the transimpedance amplifier is provided by a first feedback resistor 112 and a second feedback resistor 114. The differential transimpedance amplifier stage converts the AC current signal to an amplified AC voltage signal, and provides
10 the amplified AC voltage signal to a limiting amplifier stage 21. The limiting amplifier stage includes a first, second, and third limiting amplifiers 116, 118, 120 operably coupled in series. The limiting amplifiers receive the amplified AC voltage signal and generate an output signal whose amplitude is conditioned by
15 the limiting amplifiers.

The LOS circuit 103 coupled to the photodetector circuit includes a monolithic current to voltage converter circuit 121. The current to voltage converter circuit receives a DC component of the photodetector signal from the photodetector circuit. The current to voltage converter circuit amplifies the DC current signal, and generates a DC voltage signal 123 from the DC current signal. The current to voltage converter provides the DC voltage signal to a comparator.

The comparator circuit also receives a reference voltage signal 123 generated by a reference voltage generator 122. The comparator compares the DC voltage signal with the reference voltage signal. If the DC voltage signal is higher than reference voltage signal, the comparator generates a differential LOS signal including a high voltage signal at a non-inverting output 126 and a low voltage signal at an inverting output 128. A level translator circuit 129 receives the differential LOS signal and generates an adjusted LOS signal 130 whose output levels are compatible with standard digital logic levels.

FIG. 4 is a block diagram of a current-to-voltage convertor
35 circuit in accordance with an embodiment of the present

invention. The current-to-voltage converter circuit is implemented using MESFET technology. The current-to-voltage
5 convertor circuit receives a DC current signal 17. The DC current signal is provided to a current mirror 300. In addition, the current mirror receives a current mirror reference signal 314 and a temperature and process compensation signal 316. The current mirror reference signal is generated by a current mirror
10 reference generator 312. The temperature and process compensation signal is generated by a temperature and process compensation signal generator 310.

The current mirror uses the DC current signal, the current mirror reference signal, and the process and temperature compensation signal to generate an intermediate DC current signal
15 302. The intermediate DC current signal flows through a load resistor 304. The intermediate DC current signal current flowing through the load resistor creates an intermediate DC voltage signal 306 that is received by a voltage buffer 308. The voltage buffer generates a DC voltage signal 325 using the intermediate DC voltage signal. The DC voltage signal is then made available
20 for further processing within the LOS circuit.

FIG. 5 is a schematic diagram of an embodiment of a current to voltage convertor circuit used within an exemplary embodiment of a LOS circuit in accordance with aspects of the present invention. A cascaded current mirror is formed by transistors J1 400, J2 402, and J3 404. A DC current signal 451 flows through transistor J1 and generates an intermediate DC current signal 453 flowing through transistor J2. The intermediate DC current signal also flows through transistor J3, which forms the cascode transmitter. The base of transistor J3 is coupled to a current mirror reference.
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The current mirror reference includes transistors J4 406 and J5 408, with transistors J4 and J5 being gate coupled and forming a current mirror with the gate at J4 also coupled to the drain

of J4. Resistors RS4 412 and RS5 414 are coupled to the sources
5 of transistors J4 and J5. The drain of transistor J4 is coupled
to resistor RL1 410. The source of transistor J5 is coupled to
the gate of transistor J3.

The intermediate DC current signal also flows through load
resistor RL 455 thus generating an intermediate DC voltage signal
457. The intermediate DC voltage signal is applied to an output
10 buffer. The output buffer is formed of a stacked transistor pair
J1B 416 and J2B 418, with a level shifting resistor RSB 420
between the transistors J1B and J2B. The gate of transistor J1B
receives the intermediate voltage signal. The gate of resistor
15 J2B receives a voltage signal from the midpoint of a voltage
divider formed of resistors 459 and 461.

The current to voltage convertor circuit utilizes substrate
drive on transistors J1 and J2 to reduce current gain variation
created by variations in manufacturing processes used to
manufacture the current to voltage convertor circuit, as well as
for temperature variations. The substrate of transistors J1 and
20 J2 is coupled to a network formed of resistor RLB 422 and
transistor J2BS 420. The drain of transistor J2BS provides the
substrate bias control signals. The transistor J2BS is coupled
to a voltage source by a bias resistor RLB. The gate of the
25 transistor J2BS is drain coupled. The voltage at the drain of
transistor J2BS, therefore is dependent on the threshold voltage
of the device. The substrate bias control voltage is at a high
level when transistor J2BS has a high threshold voltage and is
at a low level when J2BS has a low threshold voltage. Resistor
30 RLB is used to bias transistor J2BS in the saturation region.

Transistor JST 424 is used to compensate for sub-threshold
currents generated by transistor J2 when there is no input
current at the drain of transistor J1 or when the gate-to-source
35 voltage of J2 is zero. The drain of transistor JST is coupled
to Vcc and the source is coupled to the drain of transistor J3.

Sub-threshold currents may become quite large at high
temperatures and hot corners of the process and cause the DC
5 voltage signal 25 to be pulled well below that of the reference
voltage signal 123 (FIG. 2). This may produce a false indicator
that there is an optical signal received by the photodetector
circuit 12 (FIG. 1) even though there is none.

The comparator stage includes hysteresis to prevent chatter
10 when the DC voltage signal is noisy and is close to the reference
voltage signal. FIG. 3 is a graph showing the hysteresis of an
exemplary embodiment of a LOS circuit including a comparator
circuit with hysteresis in accordance with the present invention.
An independent axis 200 represents photodetector current output,
15 and a dependent axis 202 shows a LOS signal voltage. A high LOS
signal voltage level indicates that an optical signal is present,
and a low LOS voltage signal indicates that no optical signal is
present. A high-to-low transition 204 indicates a de-assert
current level 206 and a low-to-high transition 208 indicates an
20 assert current level 210. A spread between the de-assert and
assert current levels 212 is a measure of the hysteresis of the
comparator circuit included in the LOS circuit.

Although this invention has been described in certain
specific embodiments, many additional modifications and
variations would be apparent to those skilled in the art. For
example, it would be clear to those skilled in the art that even
though a exemplary embodiment of a LOS circuit has been presented
based on GaAs MESFET technologies, other embodiments of a LOS
circuit in accordance with the present invention may also be
30 implemented using many other technologies. It is therefore to be
understood that this invention may be practiced otherwise than
as specifically described. Thus, the present embodiments of the
invention should be considered in all respects as illustrative
and not restrictive, the scope of the invention to be determined

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by claims supported by this application and the claims' equivalents rather than the foregoing description.

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